MOTION IMPARTING DEVICE

FIELD OF THE INVENTION

The invention relates to a novel method and device for imparting motion to fluids and solids at arbitrary rates with high efficiency.

BACKGROUND OF THE INVENTION

Micro-pump devices are essential building blocks in MEMS and BIO-MEMS technology. Many state-of-the-art micro-pump devices are based on a deformable element (e.g., plate or membrane) that vibrates periodically. The deflections of the deformable element are utilized to induce motion in confined fluids, often with the assistance of valves. To ensure sufficiently large deflections, these devices are operated at the *resonance frequency* of the system. In other operation frequencies, the achievable deformation is much lower, and much of the supplied power is invested in deforming the structure.

Furthermore, in the current state-of-the-art methods, achieving high pressure requires the use of a series of separate pumping chambers that successively increase the fluid pressure. This is due to the limitations on pressure increase attainable in each pumping chamber.

BRIEF DESCRIPTION OF THE INVNETION

There is thus provided, in accordance with some preferred embodiments of the present invention, a device for inducing motion on fluids or solids, the

device comprising:

a structure with a deformable sheet compressed to form a structural wave; and

a actuator for actuating the deformable sheet and driving the structural wave in a predetermined manner.

Furthermore, in accordance with some preferred embodiments of the present invention, the deformable sheet is a deformable plate, peripherally supported by a frame.

Furthermore, in accordance with some preferred embodiments of the present invention, the deformable sheet is a beam.

Furthermore, in accordance with some preferred embodiments of the present invention, the beam is coupled to an elastic foundation.

Furthermore, in accordance with some preferred embodiments of the present invention, a first wall is provided against the deformable sheet so as to define a first conduit between the first wall and the deformable sheet.

Furthermore, in accordance with some preferred embodiments of the present invention, the first conduit is provided with an inlet and an outlet.

Furthermore, in accordance with some preferred embodiments of the present invention, the device is further provided with a second wall positioned opposite the first wall, with the deformable sheet between the walls, the second wall defining a second conduit between the second wall and the deformable sheet.

Furthermore, in accordance with some preferred embodiments of the present invention, the second conduit is provided with an inlet and an outlet.

Furthermore, in accordance with some preferred embodiments of the present invention, the actuator is selected from the group including: electrostatic actuators, piezoelectric actuators, thermoelastic actuators and magnetic

actuators.

Furthermore, in accordance with some preferred embodiments of the present invention, some or all of the device is made from silicon.

Furthermore, in accordance with some preferred embodiments of the present invention, there is provided a method for inducing motion on fluids or solids, the method comprising:

providing a structure with a deformable sheet formed to present a structural wave,

displacing the structural wave,

thereby imparting displacing forces on a adjacent fluid or solid.

Furthermore, in accordance with some preferred embodiments of the present invention, the actuator is operated to continuously displace the structural waves.

Furthermore, in accordance with some preferred embodiments of the present invention, the deformable sheet is a deformed using a peripherally supporting frame.

Furthermore, in accordance with some preferred embodiments of the present invention, actuation of the deformable sheet is selected from the group containing: electrostatic actuation, piezoelectric actuation, thermoelastic actuation and magnetic actuation.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS

In order to better understand the present invention, and appreciate its practical applications, the following Figures are provided and referenced

hereafter. It should be noted that the Figures are given as examples only and in no way limit the scope of the invention. Like components are denoted by like reference numerals.

Fig. 1a illustrates a structural wave formed on a clamped plate of a micro-device, in accordance with a unilateral preferred embodiment of the present invention.

Fig. 1b is a cross-sectional view of a unilateral micro-pump device, in accordance with a preferred embodiment of the present invention, illustrating an induced traveling structural wave.

Fig. 1c is a cross-sectional view of a bilateral micro-pump device, in accordance with a preferred embodiment of the present invention, illustrating an induced traveling structural wave.

Fig. 2a illustrates a structural wave bonded to an elastic foundation.

Fig. 2b is cross-sectional view of a micro-pump device in accordance with another preferred embodiment of the present invention, incorporating an elastic foundation.

Fig. 3 is a cross-sectional view of a micro-pump device in accordance with another preferred embodiment of the present invention, incorporating electrostatic actuation.

Fig. 4 illustrates a pre-buckled circular plate suitable for incorporation with a micro-pump device in accordance with another preferred embodiment of the present invention.

Fig. 5 is a micro-pump device in accordance with another preferred embodiment of the present invention, used for inducing motion in solids.

DESCRIPTION OF THE PRESENT INVENTION

An aspect of the present invention is the provision of a micro-device, which employs buckling of a deformable structure in the form of a sheet, so as to induce a traveling wave on the sheet.

Another aspect of the present invention is the utilization of the traveling wave induced on the deformable sheet to impart motion to fluids or solids.

In the novel pumping method and apparatus of the present invention described herein, large deflections of the deformable element are achieved by means of buckling induced by compressive stress. Due to the buckling, deflection waves are generated in the deformable structure. For specific geometries of the system, these deflection waves can be continuously displaced. This displacement requires minimal power because the waves are already formed and only need to be relocated along the structure. The displacement of the structural waves can be achieved using various actuation methods (e.g.,

electrostatic, piezoelectric, magnetic and other).

The displacement of these structural waves can be used to induce motion in surrounding or confined fluids, to increase the pressure of confined fluids, and to displace solids that are in contact with the structural waves. In these applications, most of the power is directly invested to induce the flow, increase the pressure, or to accelerate solids, respectively.

In this invention the generation of elastic structural waves is separate and independent of the process of displacing these waves.

According to the new method of the present invention the device can be operated at any frequency without significantly affecting its efficiency. Accordingly, the device is not restricted to operate in any resonance frequency. Most of the power consumed by the device is directly invested in overcoming the drag forces in the pumped fluid, in increasing the fluid pressure, or in accelerating solids (depending on application).

Furthermore, achieving high pressure only requires the use of a longer deformable element with more structural waves. This eliminates the necessity to use a succession of many pumping chambers (with all the valves that separate each chamber from its neighbors).

Reference is now made to the accompanying figures.

Fig. 1a illustrates a structural wave formed on a clamped plate of a micro-device, in accordance with a unilateral preferred embodiment of the present invention.

Fig. 1b is a cross-sectional view of a unilateral micro-pump device, in accordance with a preferred embodiment of the present invention, illustrating an induced traveling structural wave. A micro-pump device, generally denoted by numeral 10 comprises a deformable plate 12, which is subbjected to peripheral compressing forces inflicted by frame 14, thus producing a wave structure on the

deformable plate. A wall 16 is provided, defining a conduit between the plate and the wall, leaving two opposite openings (outlet and inlet).

Fig. 1c is a cross-sectional view of a bilateral micro-pump device, in accordance with a preferred embodiment of the present invention, illustrating an induced traveling structural wave Here an additional wall 17 is provided opposite the wall 16, encasing the deformable plate 12. In this way fluids are pumped via twin inlets and through to twin outlets.

Fig. 2a illustrates a structural wave bonded to an elastic foundation.

Fig. 2b is cross-sectional view of a micro-pump device in accordance with another preferred embodiment of the present invention, incorporating an elastic foundation. Here an elastic deformable foundation 22, with a thin deformable beam 24 coupled to the surface of the elastic foundation, is held by frame 26. An opposite wall 28 is provided, defining a conduit between the thin beam 24 and the wall 28. As the thin deformable beam is actuated a traveling wave is induced producing pumping forces through the inlet through to the outlet.

Fig. 4 illustrates a pre-buckled circular plate suitable for incorporation with a micro-pump device in accordance with another preferred embodiment of the present invention.

Fig. 5 is a micro-pump device in accordance with another preferred embodiment of the present invention, used for inducing motion in solids.

When the structural wave is made to travel it induces pumping forces in the direction of travel causing fluids that are present at the inlet to be pumped through the conduit and out of the outlet.

In accordance with a preferred embodiment of the present invention a pre-buckled elastic structure is provided that includes many structural waves. This may be for example an elastic plate that is clamped along its circumference or a thin beam bonded to an elastic foundation. Internal stress induces structural deformation waves in the plate or beam.

Another possible embodiment of the present invention is using a flexible corrugated membrane in place of the pre-buckled plate. Such a membrane is shaped with waves occurring naturally in preferred regions.

The structural waves may be displaced with little effort by means of various methods of actuation (e.g., electrostatic, piezoelectric, thermoelastic, magnetic, and other actuation methods). For example, the elastic element in Fig. 3 is driven by electrodes 30 from above and below the pre-buckled plate. This may be achieved, for example, by electrically grounding the plate and applying selected voltages to the electrodes that are coated by an isolating layer.

The effort required to displace the structural waves depends on the geometry of the system. For example, the displacement of the structural waves in the pre-buckled circular plate shown in Fig. 4, require virtually no power (due to the axi-symmetry of the system).

The traveling structural wave obtained by continuously displacing the structural waves, may be used to: induce flow in a surrounding fluid; induce a pressure increase in a confined surrounding fluid; and may be used to displace solids that are in contact with the traveling structural wave. Since the power required to displace the structural waves is small, most of the power invested in these applications is used to induce the flow, increase the pressure, or displace a solid in contact, respectively.

For example the devices described in Fig. 1b, Fig. 1c and Fig. 2b can be used to induce flow in a fluid, thus pumping it from the inlet towards the outlet. The device described in Fig. 1c can be used to induce a pressure increase in a

fluid. The device in Fig. 5 may be used to displace solid particles.

The device of the present invention can be made in any dimension. It has a particular appeal in MEMS applications. It therefore may be produced using MEMS manufacturing techniques, using, for example silicon for some or all of the device.

It should be clear that the description of the embodiments and attached Figures set forth in this specification serves only for a better understanding of the invention, without limiting its scope as covered by the following Claims.

It should also be clear that a person skilled in the art, after reading the present specification could make adjustments or amendments to the attached Figures and above described embodiments that would still be covered by the following Claims.